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## **Facilitating creativity as a core competence in Engineering Education**

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### **INTRODUCTION**

In Engineering Education (EE) as well as on an overall level in the education system there is a growing emphasis on providing students with skills and competences within innovation and entrepreneurship. This emphasis has emerged from an identified need for establishment of new enterprises, creation of new possibilities for employment and contributing to enhanced growth. Engineers are considered to play a key position in this development, and most engineering challenges call for novel solutions. Creativity is a prerequisite for the ability to combine present knowledge into new solutions, and creativity is therefore widely accepted as a necessary condition for innovation [1]. This development gives reasons to reconsider how the content in EE is taught: If creativity and innovation are the new key components in academic training of engineers it is also necessary to embrace openness to collaboration and multidisciplinary, holistic views on real life, complex problems, and design competences in EE [2]. It is also well known that there is inertia in Engineering Education to develop new structures and traditions in teaching and learning [3]. An area of tension emerges between new circumstances and old traditions in education that need to be investigated and understood. In the whole education system there is a growing interest in creative engagement of pupils and students, and the body of research in the area is growing rapidly. Research in this field has an emphasis on the role of educators in facilitating creativity, while the question of how to train educators

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in teaching creativity is less emphasized [4]. As recently pointed out by famous creativity researcher Robert Sternberg, there is not a lack of literature on what is needed – the challenge is the implementation of this knowledge [5]. One of the crucial questions becomes: How do we teach creativity to those how are going to teach creativity? At the Technical University of Denmark (DTU) a mandatory teacher training program for new educators has been held since 2004 in its present format with the aim to support new educators to a better understanding of the prerequisites for student learning and a to adopt a learning centered approach in their teaching. For some years now in the programme, experimenting is done with different approaches to fostering educators' beliefs about creativity and innovation in EE. These efforts have both aimed at promoting creativity as a helpful teaching method and creativity as a crucial core competency for engineering students. The attempts are based on approaches from creativity as mental state and what fosters it and from brain physiology and how those aspects interact [6]. Based on data from a survey and interviews with participants from the most recent version of the program this paper discuss the influence on educators' beliefs about 1) *creativity in teaching and learning*, 2) *creativity as an important engineering skill*, and 3) *desire to emphasize creativity in their own teaching*. The results of this preliminary study indicate a tendency that new educators prioritize to master a traditional way to teach at university before exploring alternative methods and competencies. It also seems like certain elements in the course material has the power to influence new educators to embrace new perspectives in EE and thereby open up for a possibility to include creativity and innovation as a part of their teaching. As a framework to understand the process the educators are going through during the teacher-training programme the taxonomy of teacher development by Peter Kugel [7] is utilized, assuming a gradual shift among the participants in the programme from first having themselves and their performances in the classroom as prime objective, to transcend over to the highest level of development where the teacher functions as a coach to the students who independent seek knowledge and develop their own ideas, i.e. being creative and innovative in their learning.

## 1 CREATIVITY AND ITS PREREQUISITS IN UNIVERISITY TEACHING

In general, creativity is becoming an increasingly popular topic, and “more creativity in society” is an expressed wish from many different stakeholders in the debate [8]. Clearly education has an important role to foster creative competences in students, or worse: diminishing them [9]. There seems to be a strong traditional approach to education that makes it difficult to implement novel ways to teach that also can foster creativity and innovation, as well as other generic competence.

### 1.1 Teaching creativity

In the scope of development of university education and teaching tradition, the topic of how to teach creativity, and teaching creatively [4], seem to attract more and more of interest from both creativity researchers and educational researchers [10]. It is becoming a ‘known truth’ that *school kills creativity* as famously explained by Ken Robinson in his books and TED talks [9]. Researchers seem to be gaining an increasing interest in both ‘how not to kill creativity’ and ‘how to retrain creativity when already lost’. This movement is concerned with the whole classical educational spectrum from pre-school to university and continuing education [4]. Creativity in education is a broad and new area of research in its initial phase and it is not our purpose to provide a full review of this research and different contributions to the field

here, although some distinctions need to be made. The first important distinction is between ‘teaching **creativity**’ and ‘teaching **creatively**’. The distinction is put forward by Selvi 2007 [6], and concerns the difference between teaching to make your pupils or students more creative, or maintain their creativity, i.e. teaching creativity, and finding more creative ways of organizing your own teaching, i.e. teaching creatively. While the distinction is in no way absolute - *teaching creatively* can surely contribute to *teaching creativity*. The other distinction we would like to make is between ‘not killing creativity’ and ‘retraining creativity’. The ‘not killing creativity’ and the ‘teaching creativity’ perspectives represent the same view on creativity in education: we have to focus on ways of making creativity a natural part of the education of our students, not necessarily as a topic of its own, but as an element included in any topic taught. Obvious examples on teaching methods where elements of creativity naturally can be included is in for example “Problem Based Learning”, “Inquiry Based Learning” and “Authentic Learning” where students work with open ended questions, problem finding, process assessment etc. On the contrary is the ‘retraining creativity’ perspective, often referred to as ‘training creativity’ or ‘creativity training’ [11]. As with the creativity and creatively distinction it is not an absolute distinction – elements from retraining can be utilized when teaching and vice versa.

## 1.2 Training the teachers

It is a central question for many universities how to support and motivate their educators to develop a professional approach to teaching and a deeper understanding of student learning. At this point a consolidated tradition in the community of universities to run teacher training programmes is developed [12]. Teaching qualifications is also to a higher extent acknowledged as a core competence for educators. Studies show if knowledge is spread among educators how to teach and more effectively support students learning much can be won in order to educate highly qualified graduates. Teacher-training programmes fill their purpose and are important [13]. The question is how far teacher-training programmes help educators to develop in their role, and if they get enough knowledge to feel comfortable enough to leave the solid tradition how to teach at university and start to use the more student focused, and student active, methods mentioned above, which also can lead to foster and retain creativity among the students. In our work we consider this as a main prerequisite for both of the approaches; ‘teaching **creativity**’ and ‘teaching **creatively**’. This is an important prerequisite if the endeavor to train university students to be more qualified as creative problem solvers, and to develop innovative capabilities during their education to engineers will succeed.

### 1.2.1 Strategies and knowledge foundation in teacher-training

If teacher-training is a central parameter to enhance the development of new teaching traditions on an overall level, where also creativity is regarded as a useful and natural part, it is important to understand how useful teacher-training programmes can be designed. Hence, from our experience teacher training programmes need to be time efficient, and have an interesting and a well-considered content with a solid research foundation. The participants need to get concrete tools and advices that are more or less directly applicable to their teaching practice so they are motivated by immediately improvements. A special condition for teacher-training programmes in EE is that teaching and learning has its foundation in a different research paradigm than realism which predominant in science and engineering. This can give reasons for doubt among engineering faculty about the reliability of scientific evidence in educational science that rest on, for example, the paradigms of

pragmatism and critical theory [14]. Traditionally the content in teacher-training programmes mostly stems from cognitive theory of constructivism. Hence, active learning and a student centered approach are bearing elements in the most teacher-training programmes. From research we know that students retain knowledge better if they are taught in this way and that they can more easily reuse their knowledge in new and different situations. In other words, the educators are to teach so they support a deep approach to learning among the students [15]. The ability to reuse knowledge in new and different contexts than where the learning is taken place and to be able to broaden the perspectives in problem-solving, are both essential elements to enable creativity. Hence, this is also the foundation to learn and develop creative, innovative and entrepreneurial abilities in education [16]. The conclusion is that the leap towards active learning in EE is crucial, not only because the students in this way learn the disciplinary content knowledge better, but also to support the important abilities to creativity and innovation among students and future engineers. We believe that teacher training has an important role in order to enhance creativity in education.

### **1.2.2 The mandatory teacher-training programme at DTU, UDTU**

The Technical University of Denmark (DTU) is a polytechnic university with about 10.000 students and 2500 in staff. At DTU there is created an ecosystem for teaching and learning development with a pedagogical coordinator and educational supervisors at each department. The core in this ecosystem is the mandatory teacher-training program, "Education in University Teaching at DTU" (UDTU, <http://www.learninglab.dtu.dk/english/kurser/undervisere/udtu>), for new educators and for everyone who are going to become an associated professor at DTU. The programme has been running in its present form since 2004 and there are approximately 72 participants divided on two teams each year following it. UDTU is a practical education in teaching and learning in Higher Education. It consists of three course modules and one project module with the length of one semester where the participants implement content from the course modules in their teaching practice and analyse the results with respect to student learning using action research methods. The program builds on the cognitive theory of constructivism and promotes active learning and a student focused approach. The overall objective with the UDTU is to enhance the participants' development as educators so they faster reach an understanding of, and an ability to, teach on the higher levels in Kugels taxonomy which are stage 4: Students as active, and stage 5: Students as independent [7]. UDTU aims for helping the teachers with the main transition in Kugel taxonomy for teacher development and help them to move from perceiving the students as receptive towards perceiving the students as active, and independent. During some years, different approaches to fostering the participants' beliefs about creativity and innovation as a core engineering competence and as teaching methods have been explored in UDTU. We try to link the theory of what creativity is and how it functions with how it can be trained within the paradigm of active learning. In the third and last course module this perspective on teaching and learning is unfolded. The content in this module is about learning as a creative process involving how to handle the human process in a learning situation e.g. motivation, the social dimensions of learning, here under group dynamics. During the last day, creativity and how it can be trained in education is specifically addressed.

## 2 EMPIRICAL STUDY

This is an initial study where we wish to try out different perspectives to train educators to teach creativity and seek some answers to how UDTU influence the participants' beliefs about 1) *creativity in teaching and learning*, 2) *creativity as an important engineering skill*, and 3) *desire to emphasize creativity in their own teaching*. The study is conducted on the team that started in UDTU during the 2014. There are 30 participants in the team, of which six are female. The underlying assumption in the initial study is that if the participants in UDTU reach the stages 4, "Student as Active" or 5 "Student as Independent" in the teacher development taxonomy of Kugel [7], it will be more natural for them to address creativity as a teaching method for enhance student learning and creativity, and to foster creativity as an important engineering competence. Regarding that little is known about how teachers can be supported in using and address creativity in teaching, it is in our interest is to investigate how well, and to what extent, UDTU supports this development.

### 2.1 The teacher development taxonomy of Kugel

As the analytic tool in this study, and as a tool to structure our understanding of the UDTU-participants movements in their attitudes towards teaching and learning and their develop processes as teachers, we have used the teacher development taxonomy of Kugel as a framework. There are many studies made about educators' development as teachers. A common trait in those is that a student-focused approach in teaching is the highest level and what is aimed for [12]. We have chosen to work with Kugel's taxonomy because it mirrors the underlying aims with UDTU. Kugel's taxonomy describes five stages on which faculty can be as teachers and in between the stages there are described four transitions. The stages are divided into two phases i) Emphasis on teaching and ii) Emphasis on learning. In the first phase the stages are: 1. Focus on Self, with the underlying question: Will I survive as a teacher? 2. Focus on Subject, with the underlying question: How can I in the best way present the beauty and richness of my subject? 3. Focus on Student: Why are the students not interested in what I am saying? 4. Student as Active. 5. Student as Independent. In between those stages there are transitions. The major transition is the one between the two phases that is taking place between Stage 3 and 4. In this transition the faculty goes from focus on the subject to focus on learning [7].

### 2.2 Survey

This part of the study includes a survey, which was sent out with open ended questions about the how the participant perceived the content. The survey was sent out after the three course modules. The purpose of the survey was to investigate what the participants find most important in UDTU, without emphasizing creativity in the questions asked. A total of 17 of 30 participants responded to the survey, and as should be expected the most prioritized, and expectedly new, content in the course was the material most emphasized in the surveys. The main topic reported by the respondents was "Constructive alignment" [15], followed by "Active Learning", which are indeed the two most emphasized parts of the material taught throughout the UDTU programme. In the more detailed analysis of the survey (not presented in-depth here), Kugel's taxonomy was utilized for dividing the respondents in three main categories, dependent on their development from i) Emphasis on teaching and ii) Emphasis on learning. The further analysis focused on the two categories related to



"Emphasis on learning", as this is considered the type of responses relevant for the topic for this paper. In this analysis it became clear that while most of the respondents showed signs of being at, or beyond, stage 4 in the Kugel taxonomy, only three times creativity was mentioned unsolicited. Still, the participants who showed clear signs of being beyond stage 3 all reported a general interest in fostering more general engineering competencies in their students, acknowledging that conveying the core topic of their teaching (e.g. quantitative food safety analysis) was not the sole purpose of their teaching. Admittedly, the response rate on creativity specifically was surprisingly low, but this is attributed to the overshadowing core topics of the UDTU program. Furthermore, no other core competency was mentioned more than creativity, pointing to the fact that, of the core competencies, creativity was the one most emphasized by the respondents. In conclusion, when asked generally about the impact of the UDTU program, the respondents clearly emphasize the main content of UDTU, not the general core engineering competencies. Looking specifically on the respondents beyond Kugel's stage 3 they all reported an interest in fostering general core competencies and of these creativity was the most emphasized.

### 2.3 Interviews

Based on the survey, six of the respondents were selected for in-depth interviews. The selection was based on the replies to the survey, and the six respondents were selected to represent both ends of Kugel's taxonomy – three considered to be in the *i) Emphasis on teaching* and three in the *ii) Emphasis on learning* category. Furthermore, gender was used as a selector to ensure an equal balance between male and female respondents. The purpose of the selection was to dive deeper into the reflections underlying the short comments collected in the survey. The interviews were semi structured around eight questions, the first seven about the consequences of UDTU generally (e.g. *"Can you mention any concrete changes that you have implemented and/or are planning to implement?"*) and finally one addressing creativity specifically (*"Overall, what is your view on creativity and innovation in your teaching, and as a teaching method?"*). This final question was formulated to ensure to get some thoughts on creativity from all respondents, but in none of the six interviews it proved to be necessary as all respondents independently addressed the topic without being prompted. While the respondents were selected to represent different stages of Kugel's taxonomy, they were surprisingly similar in their replies to the eight questions. This could of course be due to the interview situation, where it could be tempting to emphasize learning (in opposition to teaching), but it could also be a result of limitations in the first survey. In general, all respondents were highly positive to the UDTU program, and reported to be very motivated to implement several elements from the programme in their own teaching. The level of reflection on own teaching, and role as teacher, was perceived as very high, and in the interviews all respondents seemed to be on Kugel's stage 4 or beyond. But while all six respondents independently expressed an interest in implementing elements to strengthen the creative aspects of their teaching, it became very clear to the interviewers that while this was a very honest and heartfelt wish, it was still considered a 'second level' aim. In other words, all respondents focused on their own topic, and the students' learning of this topic, first, but acknowledged the importance of more creative ways of teaching and expressed a wish to implement this partially in extension of their own topic. It seemed clear that the respondents all had a deep understanding of the importance of fostering core competencies, such as creativity, in their teaching, and were motivated to do so. Still, the teaching and learning of their

own core topic was naturally the main focus of their planned changes to the teaching. Still, all respondents address the practical challenges, mainly time and effort, as the courses they teach are already filled with content. It was even more obvious in the interviews that the teachers were struggling with the transition towards perceiving the importance of *students as active* in their own learning process. During the interviews the participants expressed lots of ideas how to use creativity in their courses, both small detail changes and more conceptual changes to the way they teach. Most of the respondents mention that they consider or have tried to use some creativity methods as icebreakers and to create a social environment. Only one mentioned to use it as regular teaching methods to learn the students the disciplinary knowledge. One important finding in the interviews was that creativity means different things in different types of engineering, and need to be used in different ways and addressed accordingly. In subjects with direct connection to processes and where the students are free to come up with their own solutions to engineering problems it is easier to more direct to use creative methods. In the basic technical subjects is more challenging, but still equal important, though it can be a motivating factor for the students to enhance their learning of the basic disciplinary engineering knowledge.

### 3 CONCLUSIONS

Presented in this paper was a first initial study to find out what process are guiding this development of new educators' beliefs about their role as teachers, how to teach engineers and their perception of creativity in education. Our preliminary findings have given a clearer view and we are planning for a continual and extended investigation looking deeper into the issue of teaching educators to teach for creativity. Based on the literature review and the preliminary analysis of the empirical data presented above, some preliminary conclusions and reflections for future analysis and data collections can be drawn. First and foremost, the UDTU program seems to have a strong and positive impact on the participants, both on how to teach the core material but also in terms of teach generic engineering competencies such as creativity. Still, it becomes clear that the respondents focus on 'first things first': The most emphasised learning from the programme is related to their own teaching activities responding to the first three levels of the Kugel taxonomy although they have made the major transition to focus on student as active. Furthermore, when considering creativity as a topic or method to include in their courses, additional time and extra effort needed seem to be the biggest concerns for the respondents. In addition to the above topics, for further research we consider it important to also investigate the impact the teachers view on themselves as creative might have on their interest in teaching creatively. One of the more surprising views on creativity expressed by the participants in the UDTU programme was that "I might lose my credibility as a researcher if I teach too creatively". In the view of creativity theory in general, it is indeed hard to be successful in any field if you cannot combine the domain knowledge in novel ways, but this might not be the more general perception of creativity. Therefore it might be important to convey educators that the type of creativity we focus on is the same type of creativity they need to be a successful researcher. A developed consciousness about this fact might also support educators' understanding of how to use creativity as a teaching method, and also to remove the concern of being perceived as 'unserious' researchers for teaching creatively, but to foster a culture that goes in the opposite direction.



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